



LAWRENCE
LIVERMORE
NATIONAL
LABORATORY

Influence on the Height of Stable Boundary Layers as seen in Large-Eddy Simulations

Branko Kosovic, Julie K. Lundquist

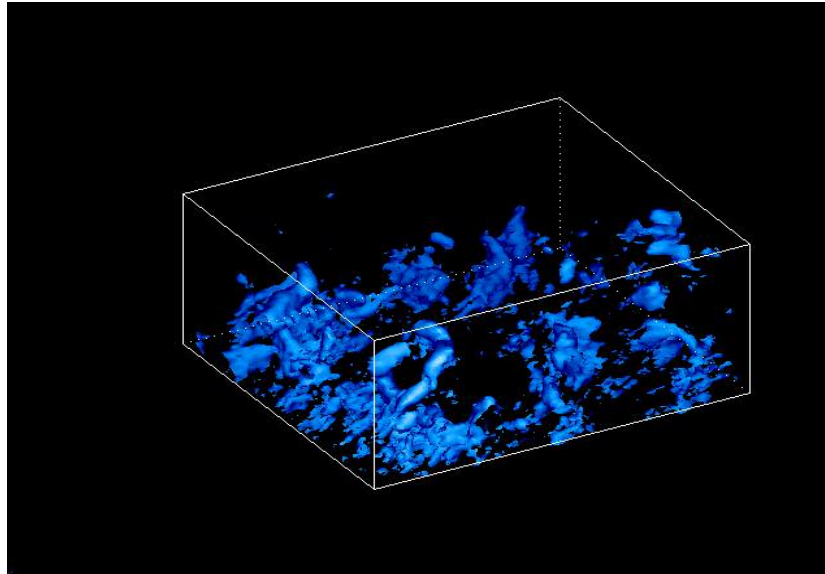
August 12, 2004

16th Symposium on Boundary Layers and Turbulence
Portland, ME, United States
August 9, 2004 through August 13, 2004

Disclaimer

This document was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor the University of California nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or the University of California, and shall not be used for advertising or product endorsement purposes.

Influences on the Height of Stable Boundary Layers as Seen in Large-Eddy Simulations



Branko Kosović and Julie K. Lundquist

Atmospheric Science Division

Lawrence Livermore National Laboratory

16th Symposium on Boundary Layers and Turbulence
Portland, Maine, August 9-13, 2004

This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.
UCRL-PRES-

Boundary Layer Height (h) is an Important Parameter in PBL models



- Boundary layer height is often used as a parameter in eddy-viscosity and eddy-diffusivity models for stable boundary layers

- Brost and Wyngaard (1978)

$$K_m = ku_* h \frac{\left(\frac{z}{h}\right) \left(1 - \frac{z}{h}\right)^{\frac{3}{2}}}{1 + 4.7 \left(\frac{z}{h}\right) \left(\frac{h}{L}\right)}$$

- Holtslag and Boville (1993)

$$K_h = kw_h z \left(1 - \frac{z}{h}\right)^2$$

- Accurate parameterization of h is important for accurate estimate of PBL bulk Richardson number
- Accurate parameterization of h is essential for accurate prediction of dispersion under stable conditions

Stable Boundary Layer Height Parameterizations



- Zilitinkevich (1972)

$$h = C_z \left(\frac{u_* L}{f} \right)^{1/2}$$

- Zilitinkevich and Mironov (1996)

$$\left(\frac{fh}{C_n u_*} \right)^2 + \frac{h}{C_s L} + \frac{Nh}{C_i u_*} + \frac{h|f|^{1/2}}{C_{sr} (u_* L)^{1/2}} + \frac{h|Nf|^{1/2}}{C_{ir} u_*} = 1$$

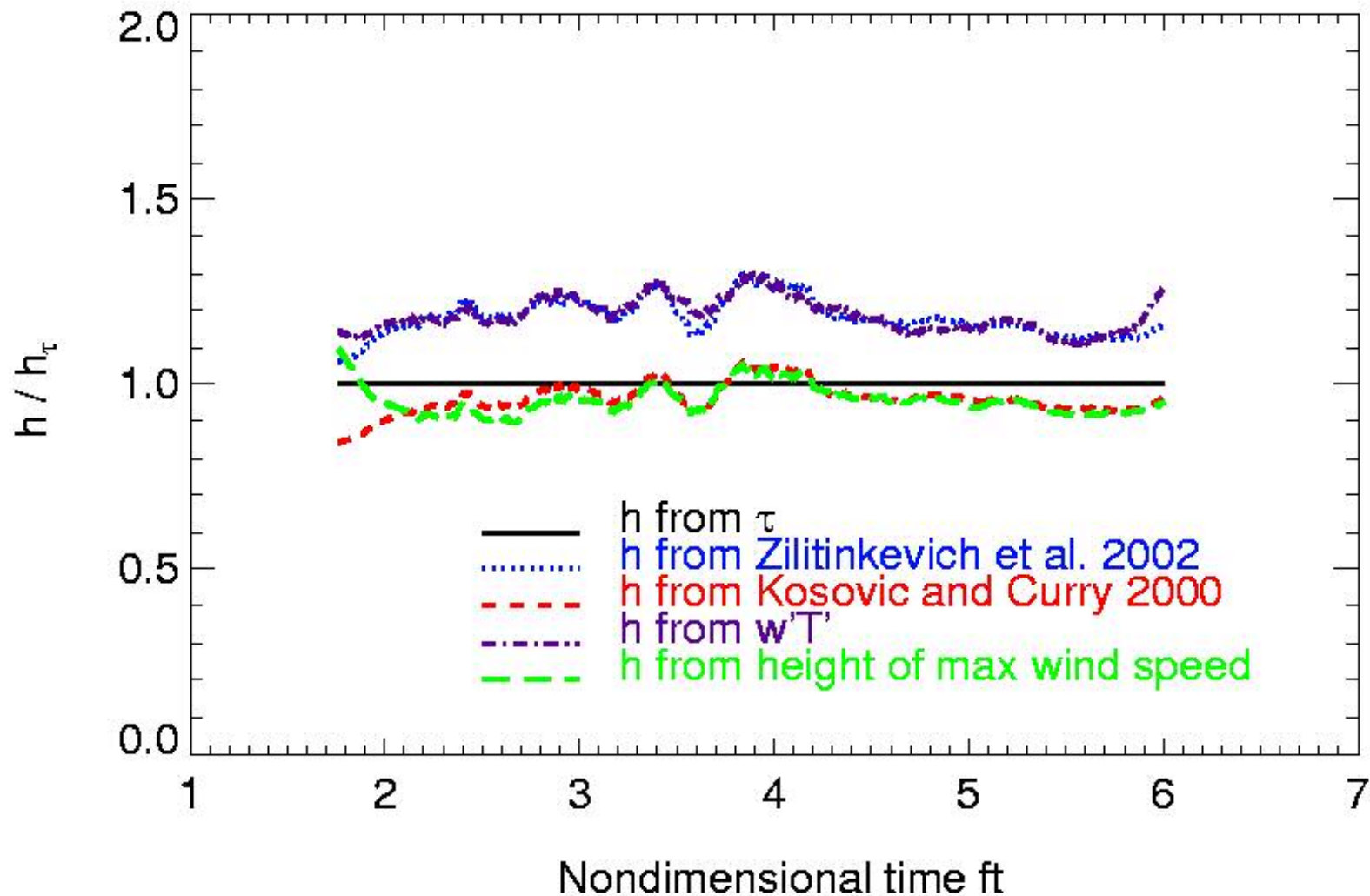
- Kosovic and Curry (2000)

$$\left(\frac{fh}{C_n u_*} \right)^2 + \frac{h}{C_s L} + \frac{h|f|^{1/2}}{C_s (u_* L)^{1/2}} = 1$$

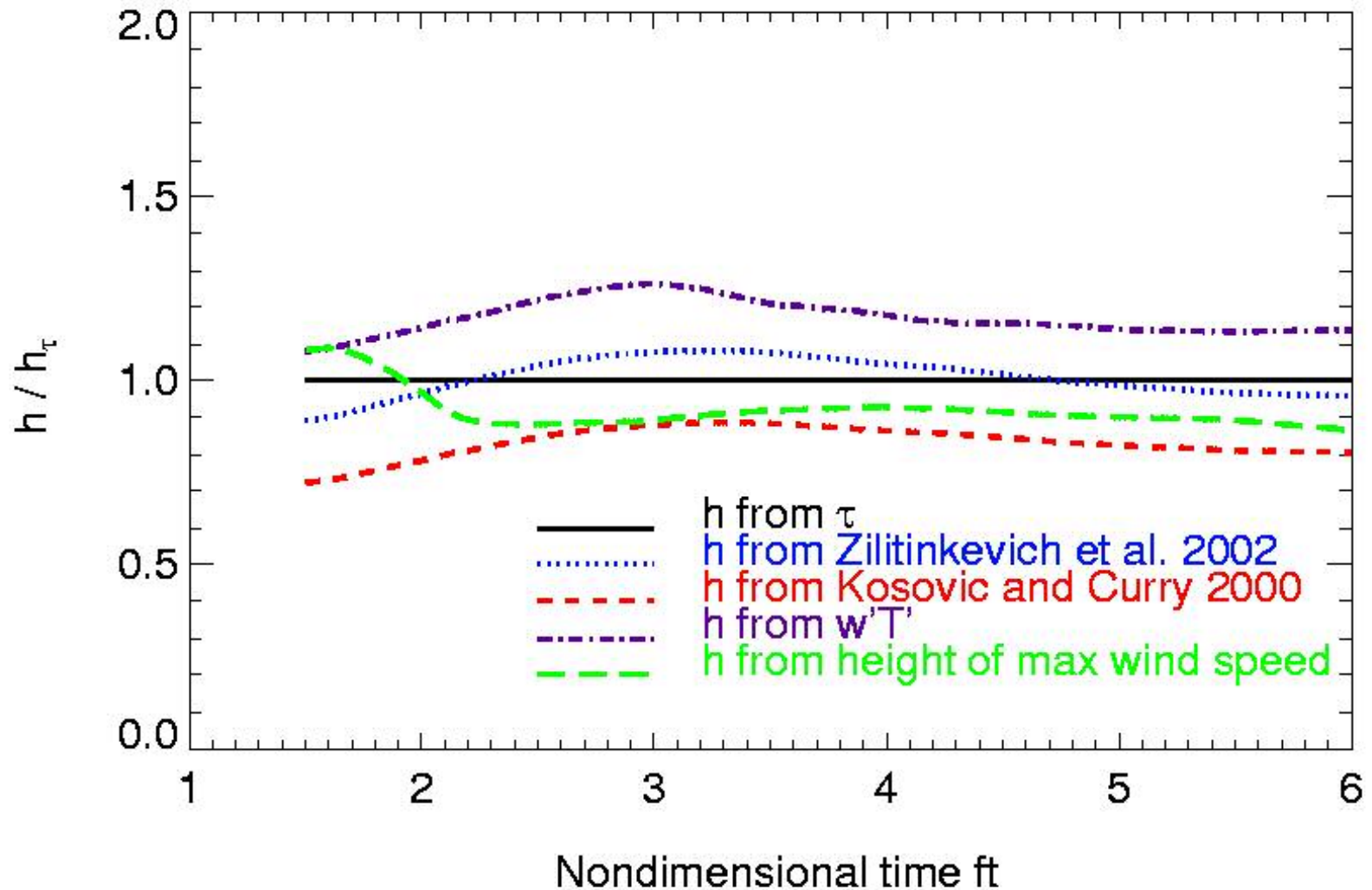
- Zilitinkevich et al. (2002)

$$h_e = C_R \frac{u_*}{f} \left[1 + \frac{C_R^2 u_* (1 + C_{UN} Fi)}{C_s^2 f L} \right]^{-1/2}$$

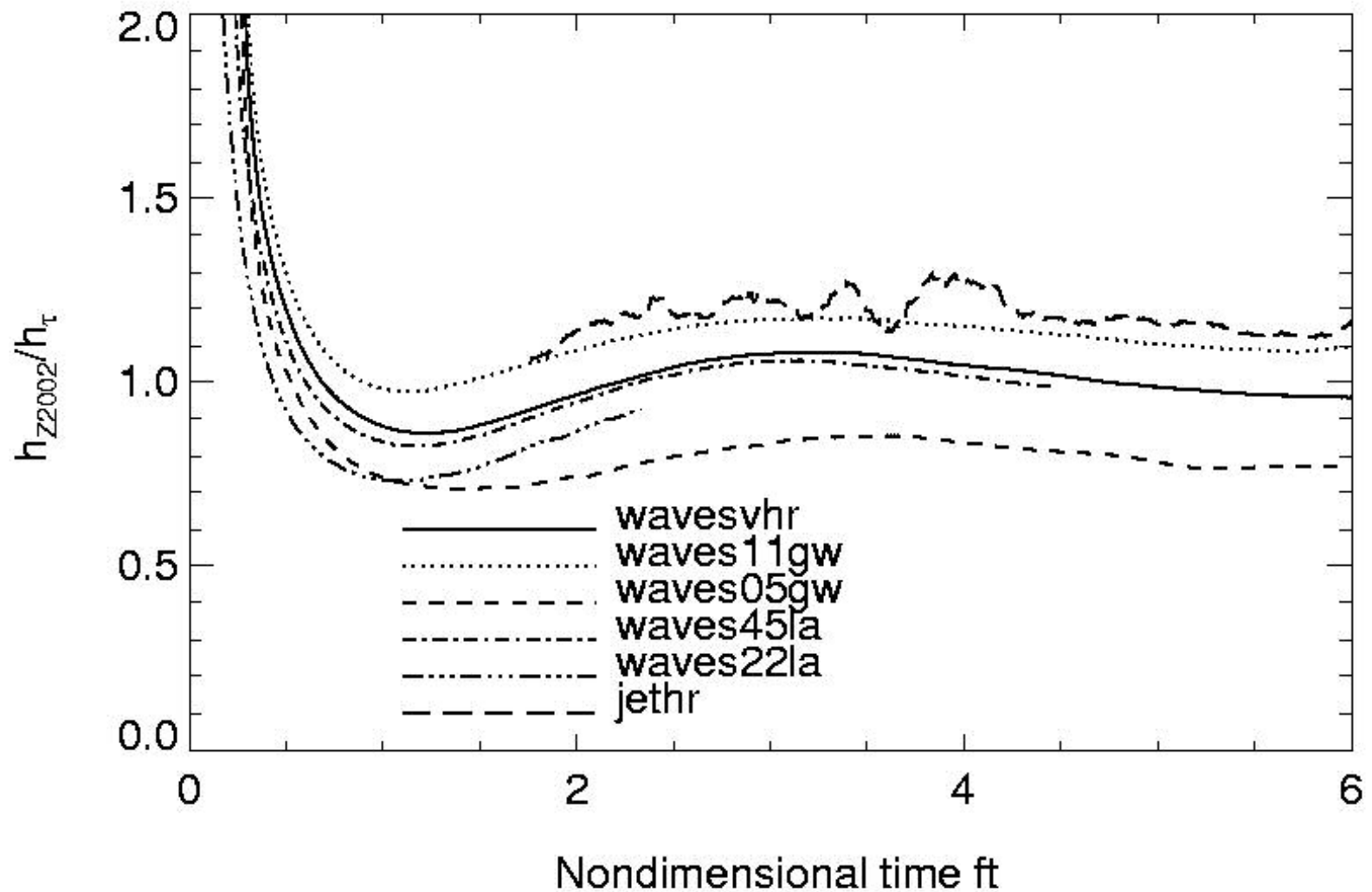
Normalized Boundary Layer Height small domain – grid size 6.25m



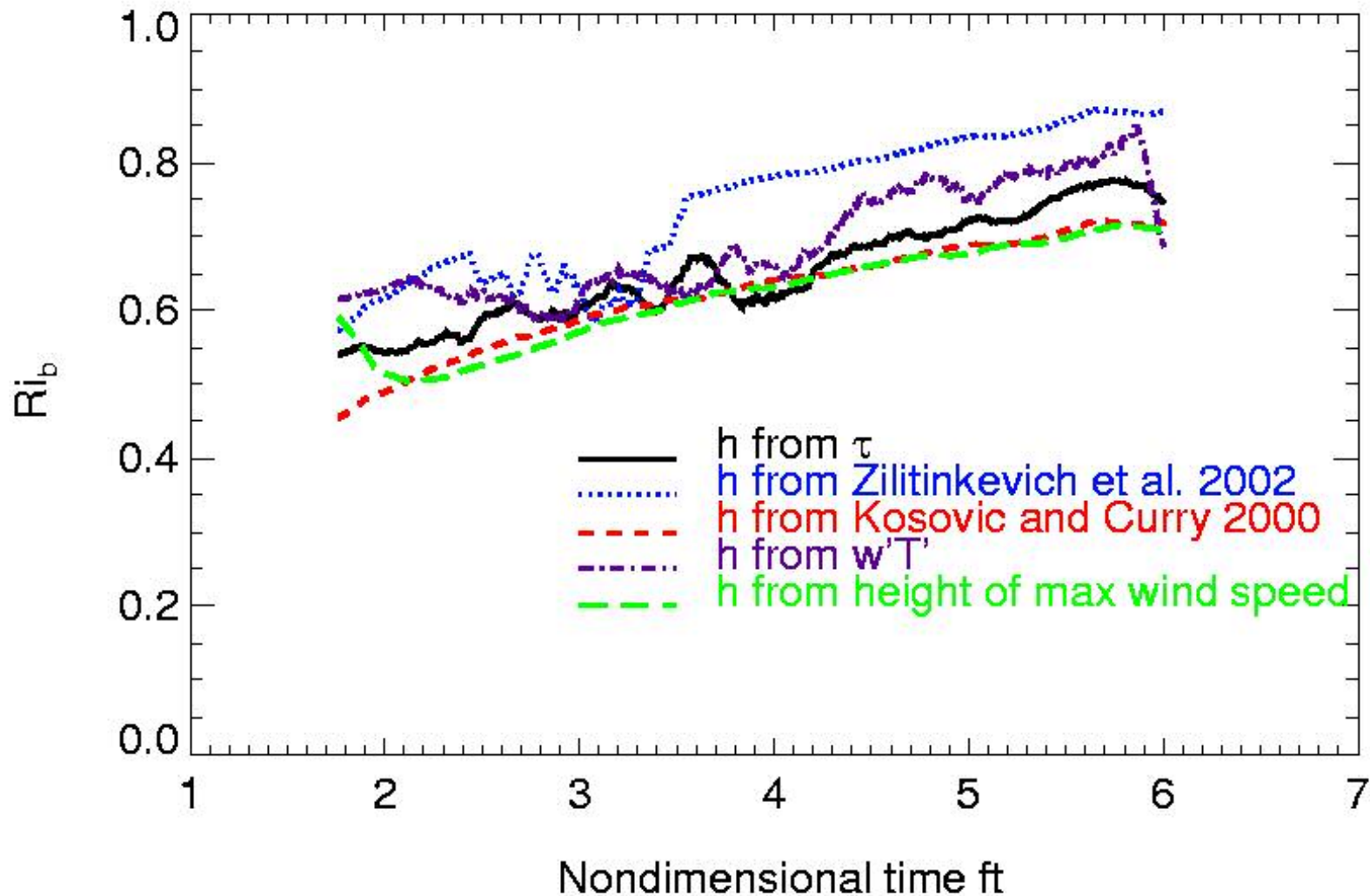
Normalized Boundary Layer Height large domain – grid size 15m



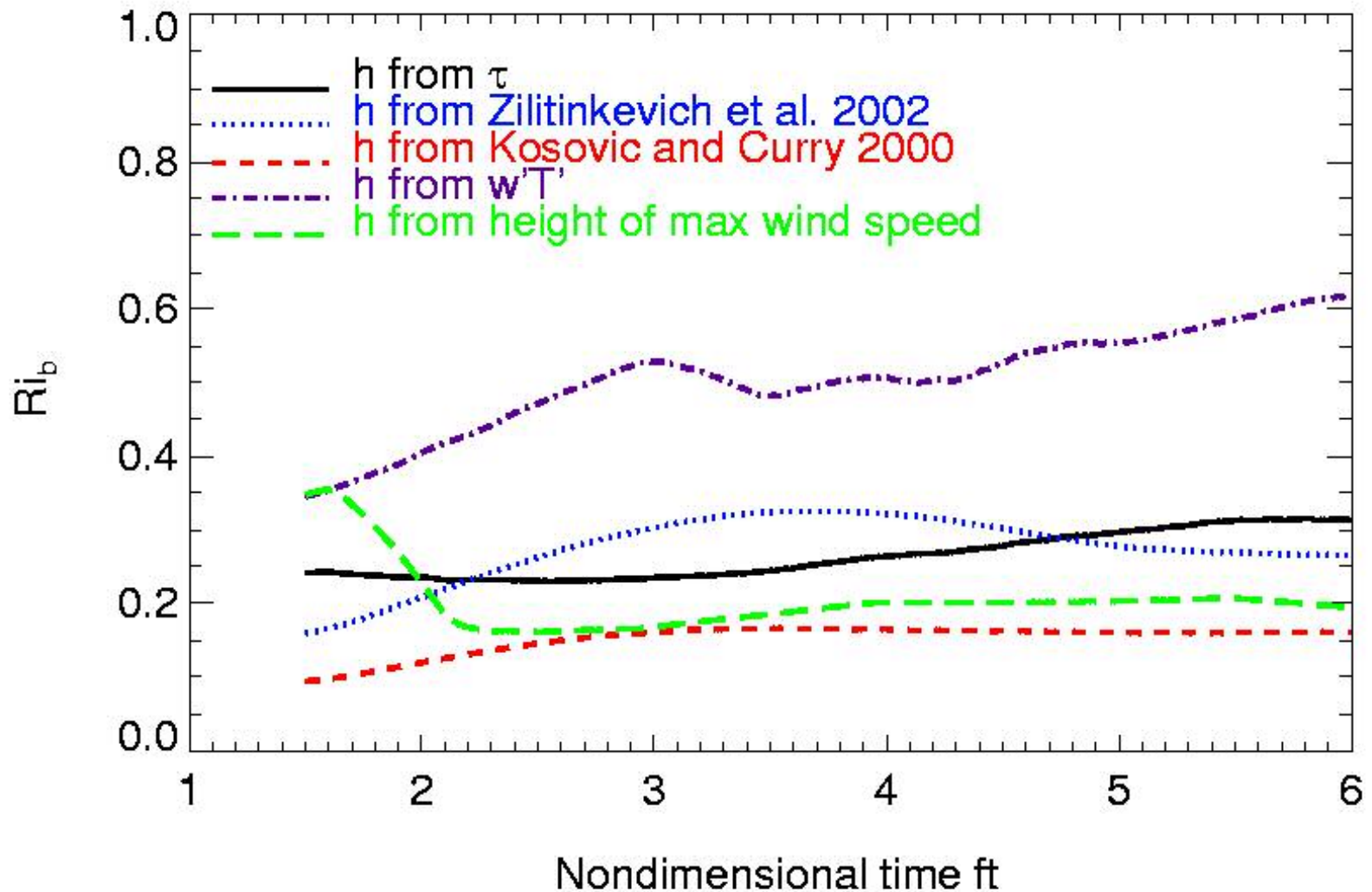
Boundary Layer Height (Zilitinkevich et al. 2002)



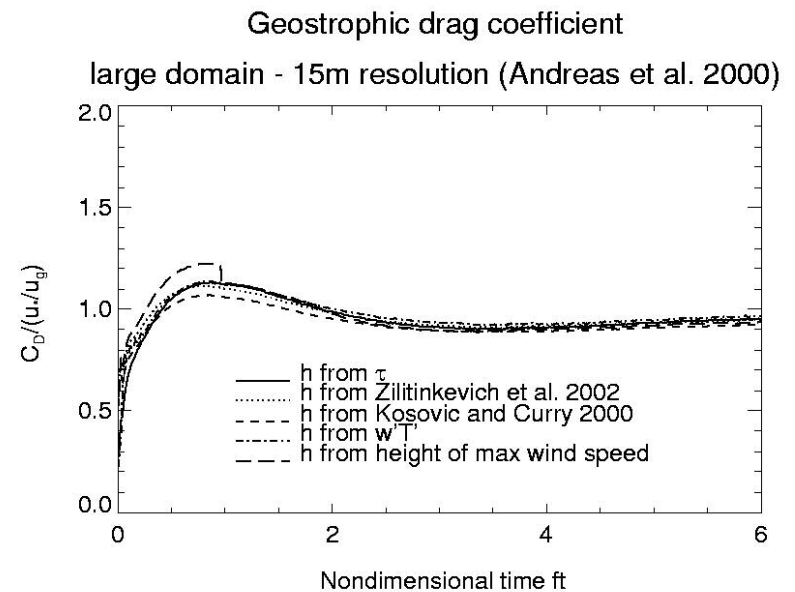
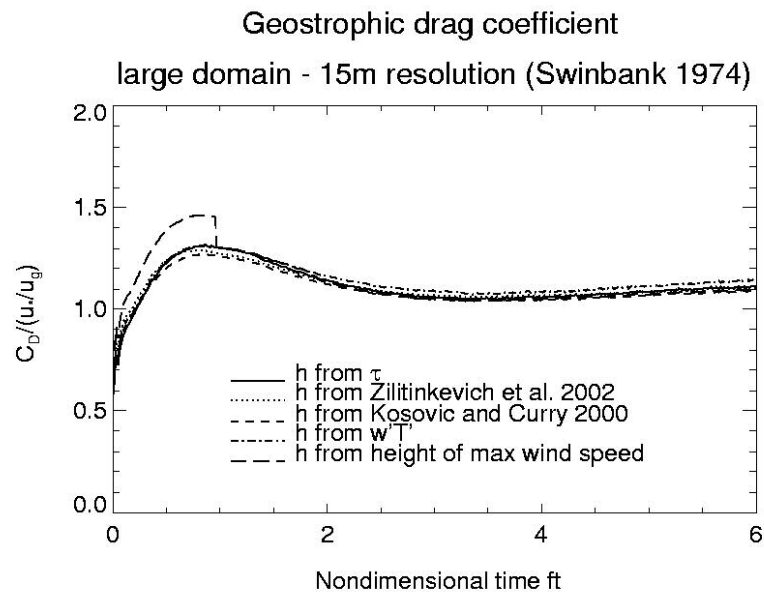
Bulk Richardson Number small domain – grid size 6.26m



Bulk Richardson Number large domain – grid size 15m



Geostrophic Drag Coefficient Computed from LES



Summary



- The height of the SBL (h) is typically used to model eddy viscosity and diffusivity; it is also important for accurate prediction of dispersion in stable boundary layers
- LES results indicate that the strength of the overlying inversion affects h via gravity wave – turbulence interaction
- The domain size for LES of SBLs must be large enough to resolve gravity waves aloft while the grid size must be sufficiently small to resolve SBL turbulence